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ABSTRACT

This paper gives an account of a pedagogical project using the computer in teaching an electrical engineering subject. The aim was to combine the computer with other activities, as one element in an active educational process. This has led to a small group instructional approach where the computer is used in various ways in courses on different levels. The various teaching activities constituting the instructional model are presented, followed by an evaluation in terms of experiences gained from several different courses in the Electrical Engineering Department. The project has provided insight into what the computer can be used for in this type of education--and what it should not be used for. Important in this context are the relationships between the computer and other educational activities and between the students and the computer. (Author/VT)

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COMPUTER-ASSISTED INSTRUCTION IN COMMUNICATION ENGINEERING

Göran Einarsson

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This paper gives an account of a pedagogical project using the computer in teaching an electrical engineering subject. The aim was not to let the computer replace the teacher but, rather, to introduce it, in combination with other activities, as one element in an active educational process. This has led to a small-group instructional approach where the computer is used in various ways in courses on different levels.
The various teaching activities constituting the instructional model are presented, followed by an evaluation in terms of experiences gained from several different courses (given at the Electrical Engineering Department, University of Lund).
The project has provided insight into what the computer can be used for in this type of education - and what it should not be used for. Important in this context are the relationships between the computer and other educational activities and between the students and the computer.
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1. INTRODUCTION

This report considers a project which was begun some years ago and which is still going on. The pedagogical approach to a subject at an institute of technology is continually changing. Perhaps the principal reason for this state of affairs is that developments in technology occur so rapidly that even after a few years, course content tends to become outmoded and no longer relevant to the industrial techniques actually being applied.

What we attempt to describe in this report is a determined effort to influence the educational process in both its form and its content. Computer-assisted teaching has come to play a significant role in our work. Yet it must also be emphasized that the computer's has been a subordinate role. The crucial contributions have been those of the teachers and the students - their contributions to the development of the working situation itself, and their achievements on the job.

In what follows, we try to present an overview of the different phases of the development project and the situation in which it was carried out. We have also attempted to summarize the results and experiences that seem the most pertinent.

The project under consideration has been going on since 1972 at the Division of Communication Theory, University of Lund, Sweden. It has come to influence not only teaching but the Division's entire approach to designing its workload and the procedures for carrying it out. In fact, we believe that the pedagogical development work can only be meaningfully described as an integral part of the total activities within the group. In summarizing our experiences, the computer's role will be analyzed carefully and opinions will be presented as to how it can most advantageously be used as a pedagogical tool in engineering education.

2. COURSE CONTENT AND EDUCATIONAL STRUCTURE

Communication Theory as taught at the University of Lund is largely theoretical and its prerequisites are mainly mathematics and mathematical statistics. Course content revolves around those aspects of telecommunication that have to do with systems, and also includes electrical network theory. Instruction deals primarily with analysis and synthesis of communications systems and parts of such systems, of both analogue and digital types. Currently (academic year 1975-1976), Communication Theory contains the following courses on the undergraduate and graduate levels:

AK:A	Analog Circuits and Systems
AK:B	Time Discrete Circuits and Systems
FK I	Analog Signals and Modulation
FK II	Digital Signals and Modulation
FK III	Information and Coding Theory
FK IV	Systems Analysis

AK indicates a general course required of all students in electrical engineering and FK indicates a more advanced course which is also an elective course. The courses involve 56 contact hours except for FK IV, which has 42 hours. These hours include all teacher-lead activities, such as lectures, exercises, labs., etc. About 100 students take the AK-courses each year and between 20-50 sign up for the FK-courses.

Instruction is based on the notion of small-group lessons. The underlying aim has been to bring about an active form of teaching containing various elements in cooperation. We regard the traditional teaching (i.e. lectures and exercises) as making the students altogether too passive. By using the combined time previously spent on lectures and exercises for small-group lessons, we arrive at an instructional model which looks like this:

- Lessons
- Laboratories
- Quizzes
- Analysis Exercises

Every period of two lesson hours normally contains a presentation of theory that is immediately illustrated with examples *and* through active problem solving. In this way, the absorption of information is spread out over a longer time, and the idea is that the student who actively follows the course in this way spares himself a large part of the cramming usually associated with preparation for examinations. To facilitate learning and to give an overview and review of the material, a number of written exercises (quizzes) are arranged during the course. These are not obligatory, but in order to encourage participation, acceptable quizzes can be counted as a small part of the examination. The objective of the analysis exercises, which are carried out by the students in teams of two, is partly to increase the students' ability to work independently and partly to provide preparation for lab work. By having the exercise conclude with a simple programming problem, a first independent contact with the computer is also accomplished.

An important aspect of such instruction by lessons is that the body of knowledge is so structured that the successive elements of the course become self-supporting - which is to say that theory-examples-practice go together and supplement each other in a pedagogically meaningful way. We have also found it valuable to encourage group unity by letting the same person conduct all the teaching. Previously, laboratories were often conducted by a separate lab assistant.

3. GENERAL EXPERIENCES WITH THE INSTRUCTIONAL MODEL

It is our conviction that the computer is most significantly exploited as an educational tool when it is used in active combination with other activities. This also implies that we do not think it possible to evaluate our experiences with computer assisted instruction in isolation; rather, such an evaluation must take place within the larger evaluation of the entire pedagogical project of which the computer was one element. This section of our report brings together the generally applicable experiences that derived from the active, group-oriented instructional model. In the next section we will consider the computer's role in detail.

Instruction in unified groups involves a new guidance role for the teacher. Because the group is small he knows each student and can individualize his teaching. This is especially important for the weaker students who otherwise can easily become too passive. Since the teacher knows the extent of each student's previous knowledge, each student can receive assistance on the most efficient level. Learning blocks due to the lack of familiarity with some aspect of the subject with which previous knowledge is assumed, can be detected at an early stage and removed. The feedback aspect is important in terms of the students' concrete possibilities of affecting the instruction. Because the teacher perceives how well the students are coping with the material, he can come up with a method wherein theory and application are combined in appropriate proportions. In this connection, it is important that the division into course elements not occur mechanically but, rather, with regard to all the ingredients of the course.

The active group also facilitates more varied forms of application than simply solving exercise problems. One possibility is discussing different methods and models and comparing their qualities and advantages. An example from our courses is that many problems can be solved through analysis in either the time domain or the frequency domain. A governing objective of our instruction model is to impart a basic understanding of theory and to train competence in simple applications. Obviously, mathematical models and methods, together with their qualities and uses, are crucial areas of knowledge.

The important thing about our concept of lessons, from the student's point of view, is that it provides an active situation for the meaningful application of the theory under consideration. This implies a greater emphasis on the exercise part of the course than if the teacher only presented the theory and taught it by solving examples. A possible weakness with the method is that the examination, which consists of a number of problems, may assume dominance. The theory may be overshadowed by problem solving since the students correctly perceive that such competence is important for passing the exam. Another problem could be that the theory might not be thoroughly digested before it is applied to solving problems. And, also, it may be difficult to gain perspective on how the various elements of the theory acquired in different parts of the course combine into a larger totality. Yet these are not serious problems; they should be avoidable through a careful planning of the courses. We recall, after all, that in the old system of lectures consisting primarily of presentations of theory, the theory gave the appearance of being clearer and more powerful than it subsequently proved to be when applications were attempted.

One objective of our instruction by lessons is the more efficient use of the students' time. The old system of separate lectures used the teacher's time effectively, but seldom the students'. Beyond any doubt, the active system of instruction by lessons is a vastly more effective work method for the average student. However, we experience the disadvantage that the very best students are probably understimulated. Since the level of instruction must be adapted to the majority of the students, there emerges a small number who finish their exercise problems before the others do, and who then have to wait for the rest. To a certain extent, this can be counteracted through flexibility in the assignment of problems, but it is difficult for the teacher to manage both to help those who have gotten bogged down and to provide additional assignments for the fast students. It can be more difficult to introduce changes in the course content in the small-group system than under the old system of lectures-exercises. The cause is partly that more teachers are involved and partly that the teaching material is more structured and thus requires a great deal more work if alterations are to be made.

The analysis exercises have the form of examples of a larger scope than one can manage to present during the lessons. The objective is for the students to practice problem solving on their own and to apply independently the

theory that was presented during the lesson. Furthermore, fulfilling the assignments serves as preparation for laboratory work. An example of an analysis exercise on analog circuits is presented in Figure 1. The exercise is followed by the network laboratory described in [1] providing further training on the properties of linear circuits. Part of an assignment implies that the students do calculations on the computer and thus provides an initial contact with the computer. This is an important aspect of the assignments. Even if this element is rather trivial in terms of programming, the students nevertheless learn to handle the computer terminal and they also gain an understanding of the computer's function. The analysis exercise is so designed as to have a direct connection to the lab work: the same programming language and the same type of calculation are involved. Thus the lab work contains elements that the student recognizes, and this implies a partial review of previous knowledge. We believe that this kind of repetition is important for the meaningful acquisition of knowledge. Since the student encounters aspects of a problem not just once but over a period of time, the assignment is used to exemplify different parts of the course and thereby helps to provide an overview and to hold the content of the course together. We think that the analysis exercises have worked well. The students have become less uneasy about working on their own, and they have acquired better motivation for problem solving. The labs have become better integrated into the courses because the exercises have functioned as a bridge. The gradual introduction of the computer at this stage has contributed notably to the effective use of the computer in later stages of the courses. One difficulty has been to adjust the demands of the assignments so they do not make too great claims on the students' time. The teachers have also been confronted with a great deal of work in the formulation of the exercises.

One objective of the active instructional model has been to give the laboratory assignments a stronger role as inculcators of knowledge. We have sought so to design their contents that they are directly tied in to the theory and the examples which have been presented in the lessons and the analysis exercises. One experience has been that the lab work should be prepared for during the lessons and in the reading of the individual student in order to function well. To reach this goal, analysis exercises and preparatory exercises are designed with an eye to the particular lab in question. When the labs have functioned best, they have constituted a point of departure for a

discussion of the theory and thus provided good motivation for the body of knowledge which is taken up in subsequent lessons. Figure 2 gives an example of the use of the computer in a laboratory in Information Theory. The students use the computer to design a convolutional encoder and to perform decoding by successively searching the resulting decoding tree. The exemplifying and concretizing which are furnished by the lab work have, we believe, resulted in increased understanding on the part of the students. In this regard, there is a certain difference between the lab work carried out on the computer and that which consists of work with instruments and other equipment. A computer lab provides understanding of the theory, while an apparatus lab also implies concretizing the conceptions which are used in the theoretical analysis. One characteristic of the labs is that they give knowledge which can, to a large extent, be described as indirect and difficult to test on an examination. This is perhaps no drawback, but it unquestionably influences the students' motivation.

Quizzes are one traditional device which we have inserted into our small-group lessons. They have functioned well, perhaps mainly because they help spread out (in time) the acquisition of knowledge. They also play an important part in sstablishing feedback between teacher and student. One experience is that it is good to avoid setting too high a level of expectations. The students might come to regard the quiz as a kind of examination on part of the course material; then (since the quiz is not obligatory) they might decide to bypass it if they have a feeling of not being sufficiently well prepared.

In certain courses we have established a course council which continuously provides observations about the educational process. This has functioned well especially in new courses. The teachers have discovered which elements are difficult and demand further exemplification, etc. We do not believe that a special course council is as necessary in a more continuous activity; the natural involvement that occurs in the small-group lesson situation quarantees that the student point of view will be expressed.

If we attempt to bring these observations together in a few words, we should begin by stating that the small-group lesson approach results in much more active instruction with a more widely spread-out exposure to the desired information than the old system of separate lectures and exercises. One bypro-

duct is a better study situation, especially for the weaker students. We also experience an improved pedagogical relation between theory and practice. For the teachers, the greater activity and interaction have implied a greater engagement and also, perhaps, greater satisfaction with their work. As a disadvantage we must mention the extra work involved in developing the courses and the greater work load that has resulted for the individual teachers. Small-group lessons with unified groups have also made it more difficult to unburden the regular teachers through the use of assistants.

4. THE COMPUTER'S ROLE

As a teaching aid, we use the computer to illustrate and clarify theoretical concepts. These can be of a basic nature, as for example the properties of different mathematical models for describing linear circuits. Its use can also be more specific, as in examining the function of a modulator for frequency modulation. What we exploit are the computer's huge computational capacity and the possibility of illustrating and handling complicated processes on the graphic terminal display. One objective is to make the use of the computer correspond as closely as possible to the way it would be used out on the job by an electrical engineer. It should be pointed out, perhaps, that instruction about computers is not included in our courses and that an elementary familiarity with programming techniques is a prerequisite before beginning studies in Communication Theory.

The most important computer activities we have tried are:

- Demonstrations
- Achievement Tests
- Analysis Exercises
- Laboratory Projects
- System Analysis
- Computer Assisted Design

A description of the different elements and a discussion of their function can be found in reference [1]. We turn next to a presentation of some generally applicable experiences from our work with the computer as an instructional aid.

When we began the project in 1972 we had great hopes for the computer as a tool for individual activity and, hence, as an automatic device for activating the students - increasing their motivation and participation. Experience indicates that this is not as simple as we perhaps thought. One thing we thought would be valuable were demonstrations with the help of the computer during the small-group lessons. In order to stimulate the students' own activity there were demonstration programs available for individual work with the computer afterwards. This did not work out as we had anticipated. Only a few students made use of the possibility of running a program on their

own. This resulted primarily from the fact that the demonstrations were too inflexible, leaving too little for the students to investigate themselves. The demonstrations also gave rise to a logistical problem since the picture terminal gave a satisfactory presentation to only a few students at the same time. All this meant that we did not find any particular use for the demonstrations as a free-standing pedagogical implement. On the other hand. they were of value in establishing student contact with the computer.

Another thing that did not work well was the attempt to check on the students' knowledge by means of a program with questions and answers. The idea was that students at the computer terminal would answer a number of multiple-choice questions and thereby test their knowledge. The reason this failed was that we used the computer for far too simple tasks where its use had no advantages. The questions and answers might first as well have been stencilled and handed out to the students.

Both of these experiences underline the importance of using the computer in ways which the user, the student, perceives as relevant and meaningful. It is important that the computer be used in connections where it is superior to other instructional devices.

The areas where we found the computer most effective as an instructional aid were analysis exercises and laboratory projects, as well as system analysis and computer assisted design. As far as the latter two activities are concerned the computer's function is natural and self-evident. It is used for calculations and simulations, and there is no need for defining or elaborating upon the computer's role in this context. The question that does arise is essentially to determine the balance between prepared program packages and programming work carried out by the students on their own. In terms of the laboratory projects the situation is different. The computer is here more obviously a teaching aid with different possible uses. In the labs accompanying course AK:A, the computer is used to clarify characteristics of, and connections between, the different mathematical models which can be used to describe linear circuits and systems. The program is largely self-instructing, i.e. it tells the student how it should be used. The computer is used here to illustrate the physical reality involved in time-continuous circuits and signals. In the following course, AK:B, which considers time-discrete cir-

cuits and signals, the computer has a further function. Because the computer itself is a time-discrete system, it can be used for realizing time-discrete circuits, providing an additional element in the teaching.

One important experience is that the students should come into contact with the computer at an early stage and acquire a grasp on how it works and how the programming is done. Otherwise one runs the risk that the more advanced computer assisted projects cannot be conducted in the intended fashion because the students are unsure of how the computer is to be used and cannot take advantage of its possibilities. In course AK:A, which is the first course taken by students in Communication Theory, we have proceeded as follows. The first contact with the computer takes the form of voluntary attendance at an evening demonstration. The next step is in connection with analysis exercises containing one part which requires a simple programming exercise to be carried out on the computer. In this way the student learns how to handle a computer terminal and acquires, simultaneously, an insight into the way a computer works and into its possibilities. It became clear that the laboratory work containing a programming system of rather demanding complexity worked better after such a progressive orientation to the computer. Thanks to the gradual contact with the computer that all students receive in course AK:A, there are no computer-related difficulties in subsequent courses where the computer is used in somewhat novel connections. The structure of the subject matter, with introductory courses followed by more advanced electives, facilitates a successive development of the use of the computer. In the later courses, the computer can be exploited in an increasingly advanced fashion.

One result of our experience that we regard as extremely important is to employ the computer in an active learning situation in such a way that there is a kind of interaction, viewed by the student as a form of cooperation between himself and the computer. As we see it this is essentially a question of the student's opportunities, and his qualifications, to run the computer. In the AK:A labs the computer program was largely in control. It asked for input, and after every completed task it inquired about what should be done next, through the presentation of a number of alternatives. Of course, the pre-planned, self-instructing program has the advantage that it can be used even by the student who has not done much preparatory work. Yet there is a risk that the student assumes an all too passive role. It is im-

portant to realize that in order for the student to learn something, it must be possible for him to make mistakes. Instruction that takes the form of successive branching makes it difficult to achieve an overview of the program's possibilities since the student encounters only one branch at a time. Repeated use of a program with varying inputs, which is essential from the point of view of learning, can also mean wasted time if every single branch has to be considered every time. On the basis of these experiences, we have modified the original version of the laboratory program and made it more flexible by providing shortcuts to be used during repeated reruns, and by cutting down on printouts. On the whole, we believe that a self-instructing program with sufficient flexibility can work well as a teaching aid, especially, as in our case, as the first advanced contact with the computer. But the basic requirement, mentioned earlier, when training students in the use of the computer, must not be neglected: the student must not simply learn to push buttons to get the computer to present a finished result.

In addition to the particular direction built into the computer program there is also a more general kind of direction of the learning process provided by the instructional material, in the form of instructions, directions and so forth. In general, the question of direction is closely associated with the degree of activity involved in the student's use of the computer. What we strive for is a situation where the student formulates problems which are then solved with the computer as a tool. The most flexible access to the computer occurs when the student is allowed to write his own program. Of course, this is normally far too time consuming, and prepared programs, or parts of programs, must be used. In this case, however, care must be taken to provide the student with meaningful possibilities for active involvement. An interesting result of our consideration of these questions is a command-directed program language, SPASS: A Signal Processing and System Simulation Package. It has been constructed with an eye to a high degree of overviewing and flexibility. It is used in lab projects in the course FK I, which deals with continuous signals and modulation methods. With its help, signals can be studied in the time and frequency domains, and different operations can be carried out, e.g. transformations and filtering. The results are presented graphically and the user can easily control the sequence of operations and study their effects. The SPASS program is illustrated in Figure 3 where it is used to visualize the sampling theorem. We believe that this kind of

program language fills an important function in computer assisted instruction since it provides a freedom of selection in using the computer that is essential for achieving an active learning situation. The only drawback we can see is that a certain training is required before one is prepared to use it. However, we have had no difficulty in this area in our courses because the work the students do with analysis exercises gives them that preparation.

An example of the use of SPASS which illustrates the computer's abundant possibilities is studying the influence of idealizations in the mathematical models used for analysis. In the mathematical treatment of circuits and systems, it is often convenient to use simple conceptions in the form of idealized spectral forms and filter functions. These have the advantage that they can be easily handled, but they also have the disadvantage that they cannot be realized with physical circuits. Yet, the computer can work with the more complicated formulas which result from the requirement of realizability. By comparing the results for realizable circuits with those obtained from the simpler idealized model, the student perceives the usefulness and the limitations of the methods used. It happens that with a suitable choice of parameters the differences are generally small, which legitimizes the use of the idealized models even though they lack a quality so apparently fundamental as physical realizability. This is a kind of knowledge which is difficult to grasp without the aid of the computer.

The work we have put into computer assisted instruction is extensive. The introductory phase, in particular, required many hours of work, and in the beginning we did not really appreciate how laborious it is to come up with program systems that work. Reference [1] presents an estimate of the volume of work required for the part of the project reported on there. In purely pragmatic terms, the project has resulted in a number of computer programs for instructional use in our courses, and we have acquired a significant experience in using the computer in engineering education. More important is our conclusion that with the computer's help we can offer a better education, one more realistically concerned with the practical needs of engineers.

Our computer system is a Hewlett-Packard 2100 combined with Tektronix 4010-1 display terminals. The systems configuration has been successively extended

from type 2000E to type 2000F. Our experiences with this equipment are good, apart from some initial difficulties. It should be pointed out that it was important for the successful realization of the project that we had, ourselves, technical competence in the area of computer sciences. For example, it was necessary for us to construct additional equipment so that the time-sharing system would function in the desired way with various external units. With regard to the technical equipment, we could have benefitted from a so-called "scan converter" which transforms the picture from a computer terminal so that it can be shown on a larger TV screen for several students simultaneously. It goes, perhaps, without saying that the fact that we owned the equipment and thus had unlimited access to it was extremely valuable. In the active learning situation for which we have been striving, it is essential that teachers and students have maximum access to the computer.

5. CONCLUSIONS

It is quite difficult to summarize a task of such a many-faceted character as this one, especially as it has been carried out over a relatively long period of time. The one result that we experience as most essential is that we have procured a more active instructional situation than that which we had previously. However, it is important to emphasize that this improvement results mostly from the changed instructional model. Of course the computer plays an important role - but that role is as one kind of teaching aid among others whose total effect is to realize the intentions of the instructional model.

An attempt at a synopsis of some of the more generally applicable experiences in employing the computer as a teaching aid might include the following points:

- The computer can constitute a remarkable teaching aid if it is given a supportive role in active combination with other activities.
- It is important to employ the computer for those tasks for which it is the most appropriate tool, i.e. where it has a meaningful function in context. DO NOT use the computer for tasks that can be carried out with simpler means.
- Try not to let the computer replace the teacher; instead, let it be a complement to the other instructional activities.
- It is essential that the student - not the computer - control the instructional situation. To achieve this, the student must have sufficient insight into the computer's function and the attributes of the program.
- The instructional programs must have sufficient flexibility and they must be structured so that they can be used actively by the student.

6. SOME PERSONAL COMMENTS

The preceding sections are an attempt at an overall account of the results and experiences which have emerged from our work with computer assisted instruction. The account is based on discussions within the group and on my own experiences. In this section, I want to offer some more personal observations.

In a time when the traditional methods of instruction have begun to feel antiquated and the demand for innovation grows continuously stronger, it is easy to overestimate the significance of new teaching tools. It is easy to convince oneself that a radical approach - for example, the introduction of computers - will solve the problems one faces. Regrettably, however, the opposite case obtains: machines do not solve problems but, on the contrary, usually create new and unanticipated problems. It is people who solve problems, and this problem solving occurs most effectively in groups of people cooperating with each other. I regard it as crucial that our work had improved instruction as its goal and that the desire to employ the computer never assumed prominence.

The computer can be used in a number of different ways in an instructional situation. It can have an administrative function wherein it is a device for the teacher to direct and control the learning situation. It can also be a means of encouraging independent activity by the students, in the form of programmed instruction. (In this function, of course, it usually acts as an alternative to teacher-lead instruction.) I think there are risks involved in both of these uses. In the first instance, the computer is a resource available only to one party in the educational situation. In the second case, the student can be alloted an all too passive part. I believe that a satisfactory result can only be achieved when the computer is assigned a diversified role in the educational process, where it can be experienced as a stimulating tool by teacher and student alike. In the previous sections attention was called to the importance of the student's being able to control the computer. I believe that it is equally important that the teacher be able to influence his working conditions by constructing or modifying computer assisted phases of the instruction. In our case this has not been a problem because the development of courses and computer programs occurs within a group where it often happened that the teacher and the programmer were one and the same person. Too, all our teachers can without difficulty modify programs

that others have made. This means that I am **sceptical** about large, centralized and "dedicated" systems of computer assisted instruction. It can easily happen that the program systems offered are difficult to comprehend and impossible to modify by the individual teacher. Another aspect of large systems packages is that they tend to be anonymous. Because of contributions by many programmers, there is literally no one who is responsible for how a system functions. Whereas one can always determine who authored a textbook, this is not necessarily the case with a computer teaching package.

The psychological aspects of the students' encounters with the computer are interesting. Elsewhere, it often happens that an attempt is made to make the contact woth the computer resemble a **real** dialogue between teacher and student. I think this is both wrong and, perhaps, harmful. It can easily lead to student insecurity and prevent the computer's being used as the effective machine it is.

A fear, or at least an apprehension, for the computer exists in many people. I think that this is a natural reaction and one which should be respected. In connection with computer assisted education more specific misgivings have also arisen in terms of viewing it as a mean for imposing control over people. I believe that there are, indeed, risks, but that they are generally exaggerated. I am hopeful that the project experience presented in this report will help to plot those risks and lead to an understanding of how the computer can be used for instructional purposes in a positive way.

7. WHO HAS CONTRIBUTED?

The project has been a real example of teamwork, with contributions from many people.

Göran Salomonsson has been a driving force with regard to the development of the instructional model and also, to a considerable extent, with regard to employing the computer therein. We have had great assistance from Anders Stenlåås, who is associated with the local Educational Development at University of Lund. He has participated actively in the planning and execution of the project, and we have made use of his knowledge of pedagogy in many discussions.

During a rather demanding introductory period we had great use of Nils Rydbeck's knowledge and contributions with regard to the computer system. During recent years, Leif Karlsson has been responsible for computer operation. Per Eriksson and Bengt Mandersson have worked with programming and have had responsibility for the project at different times. Per-Ola Börjesson supplied for the fundamental ideas and worked out a large part of the program content of the SPASS language. Others who have been involved in the project and contributed to the creation of computer assisted elements in different courses are Rolf Johannesson, Olle Pahlm and Carl-Erik Sundberg.

Economic support has come from the Office of the Chancellor of the Swedish Universities (UKÄ), making possible the completion of the computer system which was essential for carrying out the project. Contributions towards costs for personnel and materials have come from the National Swedish Board for Technical Development (STU) and from the University of Lund in the form of grants for educational development projects.

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FIGURES

Figure 1

Analysis exercise in an Analog Circuits and Systems course (AK:A).

a) The assignment to be carried out by the students in groups of two.

b) The results on the computer display terminal. The diagrams correspond to various values of the ratio R_2/R_1.

Figure 2

Example of computer-assisted instruction from a laboratory in an Information Theory course (FK III). The laboratory deals with convolutional codes and decoding by sequential decoding.

a) The student specifies a coder in terms of its generator polynomials $G_1(x)$ and $G_2(x)$. The computer then displays the corresponding circuit.

b) The student specifies an information sequence and an error sequence and the computer calculates the encoded and received sequences.

c) The student generates the decoding tree successively by letting the computer extend one node at a time. The Figure shows the tree obtained by extending at each step the node with lowest metric value (stack algorithm). The metric values shown correspond to a binary symmetric channel with $p = 0.045$.

Figure 3

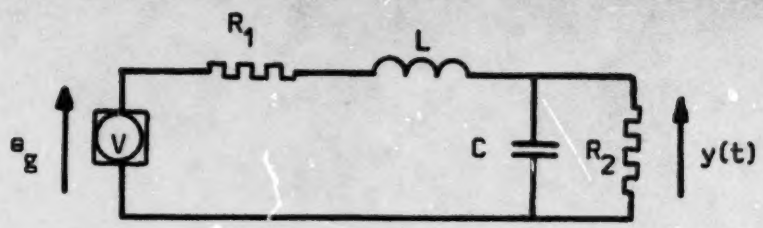
Example of the use of the SPASS program to illustrate the sampling theorem.

a) The signal and its frequency spectrum (3rd order Butterworth spectrum). The sampled signal values are indicated.

b) The frequency spectrum of the sampled signal. The original signal spectrum is shown as the dashed curve.

c) The signal reconstructed from the samples.

a)



Determine y(t) by using

- jω-method
- differential equations
- Laplace or Fourier transforms

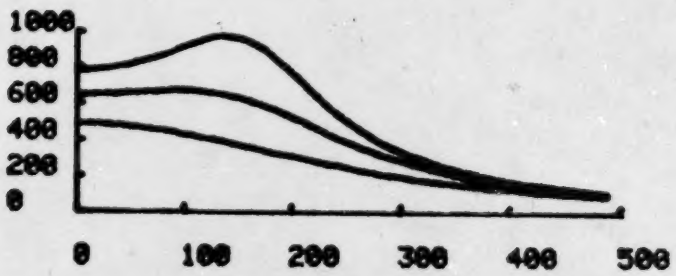
Comment on the usefulness of the different methods.

Write a simple computer program calculating

- amplitude function
- impulse response

b)

AMPLITUDE FUNCTION :

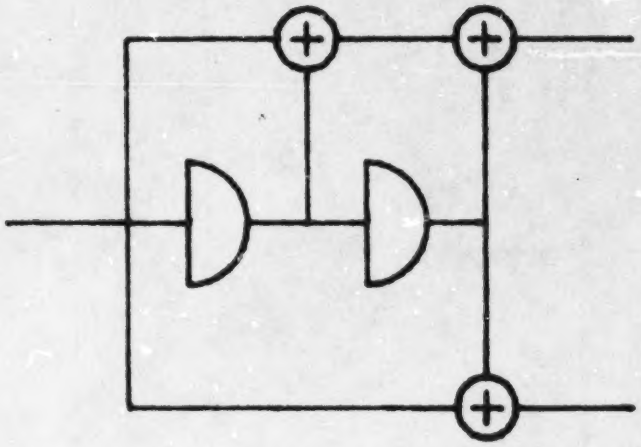


IMPULSE RESPONSE :

ENCODER POLYNOMIAL ? G1 = 7, G2 =5.

ENCODER CIRCUIT :

a)



b)

INFORMATION SEQUENCE ? 0 1 1 1 0 0 0

ENCODED SEQUENCE : 00110110011100

ERROR SEQUENCE ? 00100100010000

RECEIVED SEQUENCE : 00010010001100

c)

SEQUENTIAL DECODING TREE :

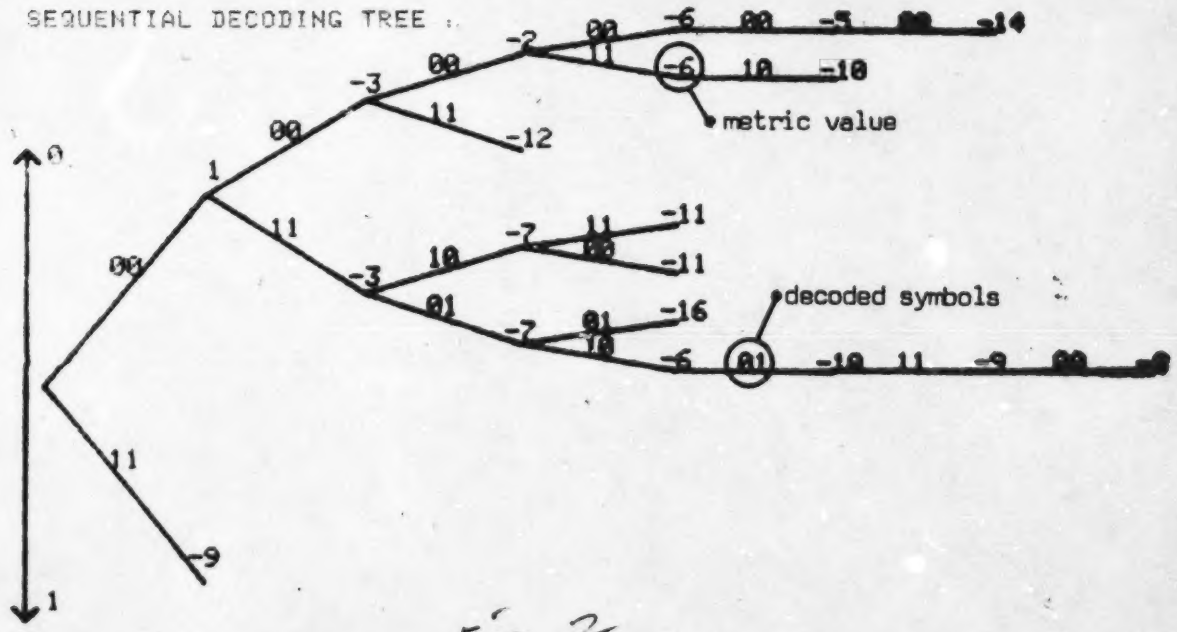
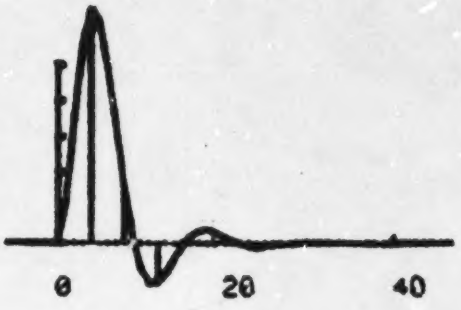


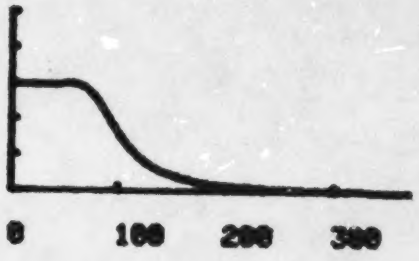
Fig 2

a)

SIGNAL:

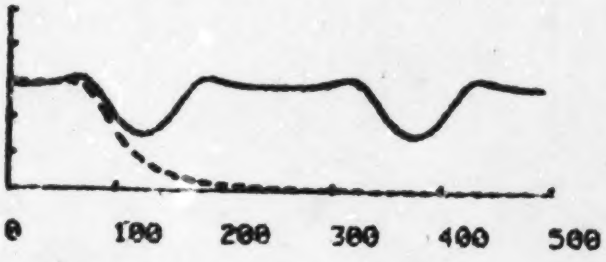


FREQUENCY SPECTRUM:



b)

SAMPLED SIGNAL SPECTRUM:



c)

RECONSTRUCTED SIGNAL:

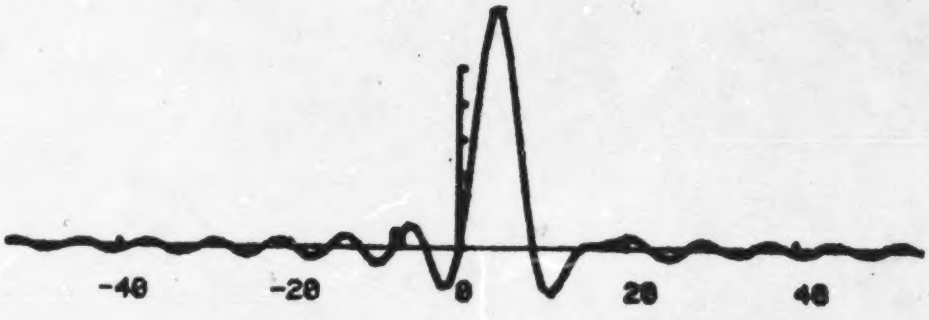


Fig. 3